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ARSENAL SHIP AUTOMATION AND MANNING ANALYSIS

by

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ARSENAL SHIP AUTOMATION AND MANNING ANALYSIS

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ABSTRACT

The Arsenal Ship concept of operations is unique. The Arsenal Ship provides a remote magazine for other joint warfare systems to utilize, with limited ability to defend itself. Ultimately it resembles a combat logistics ship designed to sail into harm's way ready to provide the initial "punch" as required. Therefore, it should be minimally manned by employing the most cost-effective technology. With the requirement to reduce crew size, a new approach to manning is required. This thesis provides an alternative approach to manning by identifying the most cost-effective investment in automation commensurate with reducing crew size to the lowest feasible level.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASRD	Arsenal Ship Requirements Document
BAQ	Basic Allowance for Quarters
BAS	Basic Allowance for Subsistence
CG	cruiser
CIC	combat information center
CONREP	connected replenishment
CONUS	continental United States
CTS	central training site
DARPA	Defense Advanced Research Projects Agency
DDG	guided missile destroyer
FOB	forward operating base
FY	fiscal year
IMAV	intermediate maintenance availability
LCC	life cycle cost
LOS	length of service
LSM	Landing Ship Medium
LSMR	Landing Ship Medium Rocket
MED	Mediterranean Sea
NBCF	Navy Billet Cost Factor (Model)

NEA	North East Asia
OPTEMPO	operational tempo
SBCM	Simplified Billet Cost Model
SC	surface combatant
SWA	South West Asia
TSSE	Total Ship System Engineering
VAMOSC	Visibility and Management of Operations and Support Costs
VERTREP	vertical replenishment
VHA	Variable Housing Allowance
WQSB	Watch, Quarter and Station Bill

EXECUTIVE SUMMARY

As intensifying national concern over the federal deficit continues to impact the budget for national defense, an Arsenal Ship design that is affordable to build, maintain, and operate must be implemented. Historically, personnel costs have had great impact on the life cycle cost of ships. Reduced manning reduces ship life cycle cost, reduces the number of personnel placed in harms way, and limits the impact on the Navy Manpower Plan. Therefore, an analysis of manning is required to determine the minimum optimal manning level that supports mission requirements. This thesis provides an alternative approach to manning by establishing the most cost-effective investment in automation commensurate with reducing crew size to the lowest feasible level. Before manning can be analyzed, factors such as locations of Forward Operating Bases, location of homeport, ship deployment cycle, crew deployment cycle and special evolution manning requirements must be determined.

This thesis selects two Forward Operating Base locations, Diego Garcia and Guam, as rational locations considering transit time and security. San Diego was chosen as the homeport because of its distance from both Forward Operating Bases. A "steady state" deployment cycle was designed in which four Arsenal Ships can be continuously forward deployed with another undergoing an overhaul in homeport for a total of five ships. This deployment cycle also insures 100 percent coverage of two theaters. The crew deployment cycle also resembles a "steady state" process in which crews train as a

team and then forward deploy for 16 weeks. Special evolutions including flight operations, underway replenishment, and General Quarters were also considered. Damage control was determined as the limiting factor for reduced manning.

Four manning structures are identified using the Naval Postgraduate School's Total Ship Systems Engineering Team design as a basis. These structures were used to develop a 30 year life cycle cost curve based on crew size. A simple spreadsheet model was designed as an alternative to the Navy Billet Cost Factor Active Component Cost Estimation Model to assist in determining a 30 year manning life cycle cost curve. This curve is similar to an economic supply curve. Automation cost curves were then formulated. The 30 year manning life cycle cost curve and the automation cost curve were then utilized to determine an optimal reduced crew target size as well as an optimal investment in automation.

I. INTRODUCTION

A. PROBLEM STATEMENT

The Arsenal Ship concept of operations is "a revolutionary approach to warfare" [Ref. 1]. Likewise, the design concept is a revolutionary approach to Naval shipbuilding. It is unlike any previous, or current, United States Navy ship design concept. Naval warships are normally designed by the Navy and built by private contractors. Shipbuilders submit proposals for construction based on the Navy's design. The shipbuilder with the "best" proposal is awarded the contract.

The new design concept encourages shipbuilders to design an independent version of the Arsenal Ship in accordance with the Arsenal Ship Requirements Document (ASRD). One of the requirements the ASRD establishes is a maximum crew size of 50. In the past, ships were built with the latest technology and the manning level was determined based on manpower requirements to maintain and operate the equipment. With the requirement to reduce crew size on the Arsenal Ship, a different approach is required. This thesis provides an alternative approach to manning by establishing the most cost-effective investment in automation commensurate with reducing crew size to the lowest feasible level.

B. BACKGROUND

In July, 1996, the Defense Advanced Research Projects Agency (DARPA) awarded five design teams Phase One contracts to design the Arsenal Ship in accordance with the ASRD. They were given six months to produce an initial proposal. On

January 10, 1997, three of five contractors were awarded Phase Two contracts to finish designing a more detailed Arsenal Ship. Next year a single contractor will be selected to build the prototype. This program is managed by the Arsenal Ship Joint Program Office for DARPA [Refs. 2 and 3].

1. Requirements

The Arsenal Ship Concept Executive Summary identifies three theaters displaying international tension which require overseas presence: North East Asia (NEA), South West Asia (SWA), and the Mediterranean (MED). Force structure requirements for the Arsenal Ship are based on continuous coverage of SWA and near continuous coverage of the MED [Ref. 2].

A primary design requirement is to reduce crew manning through the use of innovative manning concepts. Specific topics to be addressed in this area include the following [Ref. 2]:

1. Elimination of unnecessary functions
2. Reduction of on-board and Navy-wide manpower needs while maintaining effective operations, readiness and ship safety
3. Effective damage control
4. Reduction of life cycle costs (LCC)

2. History

The Arsenal Ship concept is not entirely new. Similar ships were in service during WWII and Korea. The Landing Ship Medium Rocket (LSMR) was manned with a crew of 110, including 5 officers. Converted from the hull of the Landing Ship Medium (LSM), the LSMR was equipped with up to 105 rocket launchers which included 8,000 rockets. Nicknamed "Little Ship Many Rockets", they were designed to deliver a barrage of fire support during an amphibious assault [Ref. 4]. In the late 1950's and early 1960's almost all of the 48 LSMRs were sold [Ref. 5]. Although the Arsenal Ship's mission is not solely to provide fire support during amphibious assaults, the concept is essentially the same: One ship transporting a plethora of firepower into an area of potential conflict.

C. PREVIOUS STUDIES

Using existing technology, an Arsenal Ship could be designed to operate with the minimum manning required under existing law and practice for merchant ships. In 1983, the Committee on Effective Manning was established by the Marine Board of the National Research Council to investigate the manning of merchant ships. The committee reported a statutory minimum crew of ten [Ref. 6]. The committee's minimum manning composition, along with equivalent Navy personnel, is listed in Table 1.

Merchant	Navy Equivalent	Quantity
Licensed Master	Commanding Officer	1
Qualified Mate	Qualified Officer of the Deck	3
Qualified Deck Sailor	Qualified Boatswain Mate	3
Licensed Engineer	Qualified Engineering Watch Officer	3

Table 1. Minimum Merchant Manning Comparison to Navy Personnel

In 1989, the Coast Guard requested an assessment of the effect of smaller merchant crews on maritime safety from the Marine Board of the National Research Council. Their product, Crew Size and Marine Safety [Ref. 7], includes a thorough investigation into the 1980's innovations that allowed crews of more than 30 persons to be reduced to crews of less than 20. They also developed a model to provide an estimate of minimum manning levels. The model was validated using data from a mixed product tanker and a container ship.

The minimum manning level for an Exxon® mixed product tanker was calculated using the model. The tanker had an initial crew of 18 persons. The model calculated the manning requirement could be reduced to 15 crew members. Exxon® agreed a minimum crew of 15 would be ideal. It was also noted that a crew of 15 exceeded the minimum manning requirement of 11 persons to fight an engine room fire on this type of ship.

In September, 1993, Gregory Hildebrand [Ref. 8] completed a thesis analyzing the cost benefit of a reduced active duty crew as an alternative to a civilian manning for Combat Logistic Force Ships. He found the Navy training requirements produced Navy sailors equally qualified as their civilian counterparts. Selective manning was determined to be an integral element in reducing crew size. As long as truly competent professionals are selected to fill the billets, crew reduction is feasible. Interestingly enough Hildebrand concluded a reduced Navy crew is more economical than a civilian crew, which contradicts [Ref. 9].

The Naval Postgraduate School Total Ship System Engineering (TSSE) team completed an Arsenal Ship design in December, 1996. The team modified a T-AO 201 Class fleet oiler by upgrading the engineering plant and adding weapon systems. Through automation, remote sensors and cameras, the manning requirement is reduced to 44 crew members. The engineering plant is upgraded to satisfy the sustained speed requirement of

22 knots and to provide electrical power required by the additional weapon systems [Ref. 10].

The Smart Ship initiative is another aspect of manning that must be recognized. The Smart Ship concept reduces manning through common sense approaches to manning and innovations in technology. The USS Yorktown (CG 48) is the test platform for the Smart Ship program. Matthew Fleming is completing a thesis [Ref. 11] at the Naval Postgraduate School which concludes that reduced manning is risky. "A 0.54 percent cost savings by risking the readiness of all combatants and the United States Navy seems imprudent" [Ref. 11]. There are two major differences between the Smart Ship initiative and the Arsenal Ship. First, the Smart Ship is a combatant designed to fight. The Arsenal Ship is a support ship designed to deliver a large amount of readily available ordinance. Second, the Arsenal Ship is designed to reduce the number of personnel placed in harms way. Minimizing the number of personnel at an ammunition depot is prudent. These conceptual differences make the approach to manning very different.

D. PROBLEM DEFINITION

"The Arsenal Ship concept is simple—build a ship with massive firepower which increases the capabilities of Joint Forces already in theater" [Ref. 1]. Now comes the difficult task, designing an Arsenal Ship that is affordable to build, maintain and operate. Historically, personnel costs have had great impact on LCC. Given the basic design structure, an analysis of manning is required to determine the minimum optimal manning level required to support mission requirements. In order to reduce crew size to its lowest feasible level, the most cost-effective investment in automation must first be determined.

The Arsenal Ship's mission is to provide an arsenal of weapons to end users within a theater of operations. "The Arsenal Ship is an ominous platform because it will have one principal mission: to inflict overwhelming, punishing damage" [Ref. 12]. Because the Arsenal Ship's mission resembles a fleet logistics ship more than a combatant, the manning concept is very different from a combatant. Senior ranking, highly trained, professional personnel must be selected to man the Arsenal Ship. Cross training must be extensive across all ratings. Therefore, this analysis is specialized for the Arsenal Ship and is not applicable to other warships, for example DDG-51 or SC-21. At its point of departure, this thesis utilizes the TSSE Arsenal Ship design, with minor alterations, to analyze reduced manning for the Arsenal Ship.

II. PROBLEM DESCRIPTION

A. LOCATIONS

Before explicit manning can be analyzed, location of Forward Operating Bases (FOB) and homeport must be considered. FOB and homeport locations directly impact ship deployment cycles and crew deployment cycles, which affect overall manning levels.

1. Forward Operating Bases

The Arsenal Ship Executive Summary identifies six possible FOB locations. FOBs will be used for Intermediate Maintenance Availabilities (IMAV), crew turnovers, replenishing provisions and fueling.

Transit times from FOBs to the theaters of interest are replicated from [Ref. 1] in Table 2. Forward-deploying ships to two locations vice three will reduce FOB overhead costs and the number of Arsenal Ships required. After examining transit times between the proposed FOBs, it becomes apparent that forward-deploying the Arsenal Ship to Diego Garcia and Guam is a rational decision. Transit time to all three theaters is minimized (24.2 days) when operating from Diego Garcia, making it the best overall FOB. The ability to arrive in NEA within about four days is also beneficial. Diego Garcia is a secure location since it is under long term lease from Great Britain. The ability to arrive in NEA within three days and the fact that it is a U.S. Territory also make Guam a prime FOB site. Assigning each FOB a primary and secondary theater of operations will ensure continuous coverage of at least two theaters. At 20 knots, it requires less than five days for each Arsenal Ship to transit to its primary theater. It requires less than 15 days to transit to each other's primary theater. The Arsenal Ship can enter the Mediterranean Sea within 20 days from Guam and within 10 days from Diego Garcia. However, most areas of instability can be covered without transiting the Suez Canal. Furthermore, Arsenal Ships returning from the continental United States (CONUS) are within seven days of the Mediterranean Sea if homeported on the east coast.

Forward Operating Base	North East Asia	Mediterranean Sea	South West Asia
Augusta Bay, Sicily	18	1	8
Diego Garcia	10	10	4.2
Guam	3	19	13
Yokosuka, Japan	2	20	14
Souda Bay, Crete	18	1	8
Sasebo, Japan	0	18	12.5

Table 2. After Ref. [1] Transit Days From Forward Operating Base at 20 Knots

2. Homeport

The homeport is the location for all overhauls and the Central Training Site (CTS). It is also the homeport for the families of the deploying crews. This allows the deploying crew to be home during training. In an effort to lower LCC, one location should be selected as the homeport for all Arsenal Ships.

The primary Naval bases considered in this thesis are located in Norfolk, Virginia and San Diego, California. When transit time to and from the FOBs and the theaters is the primary concern, the homeport of choice is San Diego. The transit time from San Diego to Diego Garcia and San Diego to Guam is 2/3 of the transit time from Norfolk. This thesis did not take any other factors involved with locating Naval bases into account.

B. MAINTENANCE

1. Overhaul

Overhauls must be routinely conducted because of the limited maintenance accomplished while deployed and the short IMAV periods. The overhaul will be conducted by an overhaul crew trained specifically for Arsenal Ship overhauls. The overhaul crew, which is assigned by the Arsenal Ship Squadron Commander, will be responsible for maintaining a Quarterdeck Watch, Fire Party and Security Force. Overhauls will be managed by the Arsenal Ship Squadron Commander in homeport. Therefore, this thesis assumes overhauls will be conducted in San Diego, California.

2. Intermediate Maintenance Availability

Each ship spends one month in an IMAV to complete urgent repairs and all routine maintenance with a periodicity of 90 days or more. The Arsenal Ship design should include concepts which increase periodicity of maintenance requirements beyond the normal deployment length of the Arsenal Ship. In this thesis, maintenance required while deployed is reduced by increasing periodicity between maintenance requirements to 90 days. Maintenance with a periodicity of less than 90 days must be performed by the deployed crew.

C. SHIP DEPLOYMENT CYCLES

To develop a “steady state” for Arsenal ships to operate, the following ship deployment cycle is selected. This deployment schedule requires five Arsenal Ships. Ships will deploy for 84 day periods with overlapping intervals and will be relieved on station. After nine deployments each ship will have four weeks to return to homeport for an overhaul. The percentage of time a ship is in each phase of a deployment cycle is provided in Table 3. The transit phase is the time allotted to transit to and from overhauls conducted in homeport. Each Arsenal Ship is operational 60 percent of the time using this method. Three of five ships are deployed at any one time. An additional ship is in a maintenance availability and can be deployed within a few days depending on the type of maintenance in progress. This provides 100% coverage of two theaters of operation at all times with a ready recall ship available. Appendix A provides a five ship deployment schedule. The initial forward deployments in Appendix A are irregular lengths allowing a steady state process to develop.

Phase	Time in Phase
Transit	4.4%
IMAV	17.8%
Deployed	60.0%
Overhaul	17.8%

Table 3. Percentage of Time in Each Phase

D. CREW DEPLOYMENT CYCLES

The following crew rotation is selected to resemble a "steady state" process. Crews are homeported in San Diego, California. A typical crew tour is outlined in Table 4. Sixteen weeks of initial training is followed by four weeks of team training conducted in a simulator at the CTS. After qualifying in the simulator, the crew flies to the FOB for crew turnover. After a one week turnover, the crew has two weeks to prepare the ship for deployment. The crew then deploys for 12 weeks to its primary theater of operations. Upon returning from deployment to the FOB, the crew initiates an IMAV and has one week to turn over the ship to the next crew. Once the crew returns to homeport, each crew member receives 16 weeks of combined stand down and specialty training. The type of specialty training is determined by the needs of the Navy and the professional development of the sailor. Specialty training does not necessarily have to pertain to the Arsenal Ship. The crew is reunited after the additional training phase and attends a 4 week team trainer in the Arsenal Ship simulator. After requalification, the deployment cycle begins again. The crew returns to homeport after the 16 week deployment and is detached from Arsenal Ship duty.

Phase	Length
Initial training	16 weeks
Team training	4 weeks
Deployed	16 weeks
Additional training	16 weeks
Team training	4 weeks
Deployed	16 weeks

Table 4. Typical Arsenal Ship Crew Tour

The crew on a ship scheduled for overhaul has four weeks of additional time at sea while returning the ship to homeport. Following arrival in homeport, they are relieved by the overhaul crew. If the crew returning from deployment has completed two deployments, they may request to stay onboard and augment the overhaul crew. At the end of the overhaul, the overhaul crew turns the ship over to the scheduled deploying crew. The scheduled deploying crew transits to the primary theater, completes a scheduled deployment and returns the Arsenal Ship to a FOB.

Because crew size is small and every individual is important, every effort is made in the schedule to promote high morale, crew stability, and comprehensive individual and team training. These standards should not be compromised for efficiency or cost savings as such savings were gained by minimizing the crew size to start with.

E. SPECIAL EVOLUTIONS

1. Flight Operations

Flight operations will require full crew participation. Flight operations will be utilized for all transfers at sea. Flyaway teams will be required to fly via fixed wing aircraft to the closest aircraft carrier for further transfer via helicopter to the Arsenal Ship. The following flight deck manning is proposed:

1. On Scene Leader
2. Team Leader
3. LSE
4. Nozzleman
5. Hoseman (2)
6. Hotsuitman (2)
7. Chock and Chainman (2)

The Watch, Quarter and Station Bill (WQSB), Appendix B, outlines all manning positions during flight quarters.

2. Underway Replenishment

The Arsenal Ship will be designed for underway replenishment. However, connected replenishment (CONREP) will not normally be required. The Arsenal Ship will carry more than adequate fuel to remain deployed for 90 days. CONREP is manpower intensive and should be avoided if possible. The following UNREP station manning is proposed:

1. Rig Captain
2. Signalman
3. Linehandler (7)

Vertical replenishment (VERTREP) will be the normal replenishment method. A non-organic helicopter supplied by the replenishment ship will be utilized. VERTREP is much less manpower intensive than CONREP. VERTREP manning is the same as flight operations manning except the chock and chainmen are cargo handlers.

The WQSB, Appendix B, outlines all manning positions during UNREP.

3. General Quarters

General Quarters will be required for two specific instances. Major damage control and weapons launching will require entire crew involvement at their specialty locations.

a. Launch

Since launching weapons is the Arsenal Ship's mission, it is the most important evolution the ship will perform. General Quarters will be set to maximize the probability of success.

b. Damage control

Major damage control is the most manpower intensive evolution the crew will be required to perform. To insure maximum survivability, total crew involvement and cross-training will be required. The following damage control team manning is proposed:

1. On Scene Leader
2. Team Leader
3. Nozzleman (2)
4. Hoseman (4)
5. Plugman (2)

The WQSB, Appendix B, outlines all manning positions during General Quarters.

4. Concurrent Special Operations

Concurrent special operations are not possible with the proposed manning. General Quarters for launching does not support damage control. Once damage is anticipated or realized, the Arsenal Ship will be required to transition to the damage control posture. A damage control posture includes the use of self defense weapons, but it does not include offensive weapon firing.

III. ANALYSIS

A. INTRODUCTION

In order to estimate the most cost-effective investment in automation, manning costs incurred over the Arsenal Ship's expected 30 year service life must be determined. To develop a manning LCC curve suitable for evaluating tradeoffs between manning levels and automation, a minimum of two alternative manning structures are required. This thesis develops four such manning structures. A simplified model, designed by the author and calibrated to the Navy Billet Cost Factor (NBCF) Model results, is used to estimate LCCs for each of the manning structures. The estimated costs of the four manning structures are used to calculate a life cycle cost curve using regression analysis. This cost curve is then used to examine the tradeoffs between manning levels and automation and to estimate the most cost-effective investment in automation.

B. MANNING STRUCTURES

The Arsenal Ship manning cost curve is determined using four different manning structures. One manning structure was determined by the TSSE design team, while the other three structures were determined by the author. Table 5 is a comparison of the four manning structures.

1. Structure One: Minimum

The first manning structure is based on the minimum manning level required by existing law and practice for merchant ships as discussed in Chapter I.C. The Arsenal Ship is fully automated and all functions of the ship can be monitored from one location.

Manning Comparison				
Rank/Rate	Structure 1 Minimum	Structure 2 Proposed	Structure 3 TSSE	Structure 4 Maximum
CDR	1	1	1	1
LCDR	1	1	2	2
LT	3	3	6	7
BM1	1	1	1	1
BM2	2		2	2
DC1			1	1
DC2			1	1
EM1	1	1		
EM2		1	2	2
EMC			2	2
EN1			3	3
EN2		2	1	1
ENC	1	1	2	2
ET1		1	2	2
ET2		2	2	2
ETC		1		1
EW1			1	1
EW2			1	3
GMM1			1	1
GMM2			1	1
GMM3			4	4
HM1			1	1
MS1		1	1	1
MS2		1		
MS3			1	1
OS1		1		
OS2		2		2
QM1		1		
QMC			4	4
RM1			1	1
SM1		1		
Total	10	22	44	50

Table 5. Arsenal Ship Manning Comparison

This structure does not require special manning for flight operations, underway replenishment or General Quarters. The crew's responsibility is to monitor the Arsenal Ship's systems for safety.

2. Structure Two: Proposed

The second manning structure is a notional estimate proposed by the author. This manning structure is based on a three section watch rotation with continuous watches on the bridge, in combat information center (CIC), in sensor control, and in engineering. This structure satisfies the manning requirements for flight operations, underway replenishment, and General Quarters as discussed in Chapter II.E. The lower bound for this manning structure is determined by the manning requirements for damage control since it is the most manpower intensive evolution. Once a lower bound was established, the matching of duties to personnel became a matter of job related abilities and the author's experience. The ratings selected for the duties involved are not the focus of this thesis. Because specific manning requirements cannot be determined until the Arsenal Ship design has been accepted, the pay grades selected are the real focus. The manning requirement for boat operations is eliminated by not embarking a small boat. The manning requirement for a special physical security force is eliminated by training all personnel, arming all watchstanders and providing access to additional weapons at each watchstation. The WQSB, Appendix B, provides additional details about the proposed manning structure.

3. Structure Three: TSSE

The billet structure developed in the TSSE report is used for the third manning structure. This structure is based on a four section watch rotation. Billets are separated into two categories: Watchstanders and Special Evolutions. The WQSB for the TSSE manning is reproduced as Appendix C. Additional manning for boat operations and physical security is included in this structure.

4. Structure Four: Maximum

The fourth manning structure is a notional estimate in which personnel were added to the TSSE billet structure to achieve the maximum allowed crew of 50 personnel. One officer, one chief petty officer and four second class petty officers were added to the TSSE billet structure.

C. NAVY BILLET COST FACTOR MODEL

1. Background

The NBCF, Active Component Cost Estimation Model was utilized to calculate the initial LCC estimates for the four manning structures. The model was developed for the Bureau of Naval Personnel by SAG Corporation in 1995, and is based on cost data extracted from the Office of the Secretary of Defense pay tables, allowance tables and other Navy sources. The base year costs are in FY 94 dollars. The pay tables used were effective January 1, 1995. FY 93 end strength was used as the current inventory and budget data was extracted from the FY 93 - FY 94 President's Budget [Ref. 13].

An estimated cost for each rating and pay grade is calculated using a weighted average approach. The following excerpt from the *Navy Billet Cost Factor: Active Component Cost Estimation Model Operations Manual* [Ref. 13] explains how the average basic pay is determined.

> Average basic pay is determined by first multiplying the inventory of members of all grades, lengths of service (LOS), and ratings by the basic pay rate. This figure is then summed across LOS for each pay grade and rating and divided by the total inventory for that pay grade and rating.

This yields the average annual basic pay for each grade by rating.

The model includes the following elements of manpower cost:

1. Military Compensation (Basic pay, Basic Allowance for Quarters, Basic Allowance for Subsistence and Variable Housing Allowance)

2. Retired Pay Accrual

3. Selected Reenlistment Bonus

4. Special Pays (Hazardous Duty Pay, Flight Pay, Sea Pay etc.)

5. Training

6. Enlisted Recruiting

7. Medical Support (Military Hospitals and Civilian Health and Medical Program for the Uniformed Services)

8. Other Benefits (Death Gratuities, Deserter Rewards, Survivor Benefits, Clothing Allowances etc.)

9. Permanent Change of Station

10. Officer Acquisition

11. GI Bill

12. Separation Costs

2. Initial Life Cycle Cost Results

The 30 year LCC per ship was calculated for each manning structure using the NBCF Model. The LCCs are based on constant FY 94 dollars for the entire 30 year life cycle. The results are provided in Table 6.

Manning Structure	Crew Size	NBCF Model Results (Millions)
Minimum	10	23.41
Proposed	22	43.79
TSSE	44	84.61
Maximum	50	94.68

Table 6. NBCF Model Results

Figure 1 provides the linear regression utilizing the results from the model. The regression equation is:

$$30 \text{ Year Life Cycle Cost} = (1.80 * \text{ Crew size}) + 4.98 \quad (1)$$

$$r^2 = 0.9997;\ n = 4;\ p = 0.0002$$

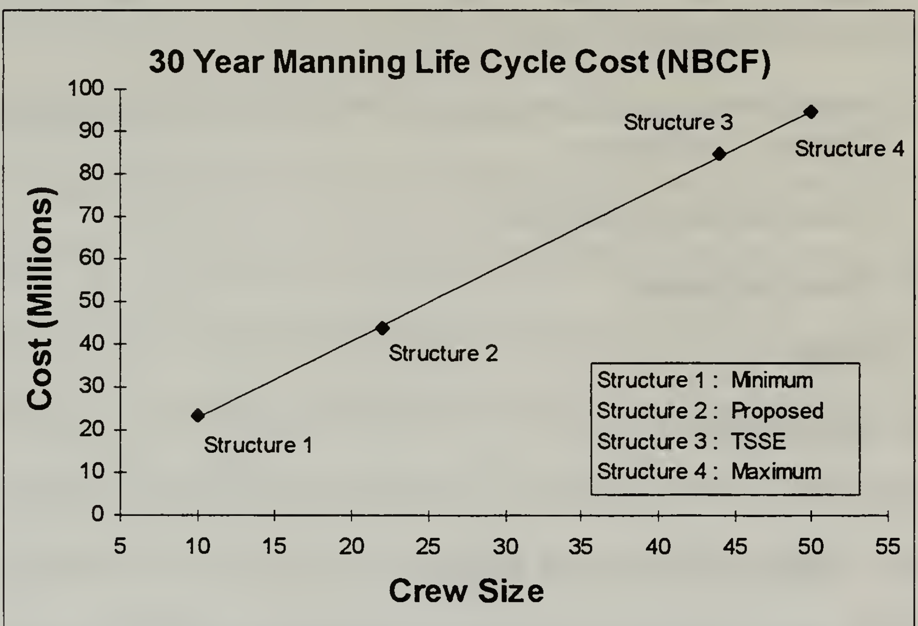

Figure 1. Initial Navy Billet Cost Factor Model Results

D. SIMPLIFIED BILLET COST MODEL

1. Background

The second model is a Simplified Billet Cost Model (SBCM) that was developed by the author as a simplified and updated model to better suit the purposes of this thesis.

The SBCM excludes data elements not required by this thesis and uses the maximum rate per pay grade instead of a weighted average calculated from a previous end strength. Since this thesis assumes that the Arsenal Ship will be homeported in a specific location, namely San Diego, the SBCM was designed to utilize specific housing allowances rather than the Navy-wide weighted average used by the NCBF Model. The SBCM can be updated to accommodate housing allowances for any location. Finally, the SBCM includes 1997 cost data obtained from the *1997 Navy Times Pay Chart* [Ref. 14]. The resulting SBCM utilizes an Excel® spreadsheet to calculate billet costs based on Basic Pay, Basic Allowance for Quarters (BAQ), Basic Allowance for Subsistence (BAS), Variable Housing Allowance (VHA) for San Diego, Retired Pay Accrual and various projected annual inflation rates. Retired Pay Accrual is assumed to be 36.4% of basic pay as in [Ref. 8].

2. Initial Life Cycle Cost Results

For comparison, the LCCs for each manning structure were calculated using the SBCM. Pay tables [Ref. 15] effective January 1, 1995, were used to correspond with the data in the NBCF model. To represent constant dollars, no annual inflation rate was used. The 1993 VHA (with dependents) rates [Ref. 16] for San Diego were used realizing that they probably do not match the weighted average VHA rate in 1993. The results are provided in Table 7.

Manning Structure	Crew Size	SBCM Results (Millions)
Minimum	10	19.20
Proposed	22	35.01
TSSE	44	69.26
Maximum	50	77.37

Table 7. SBCM Results

Figure 2 provides the linear regression utilizing the results from the model.. The regression equation is:

$$30 \text{ Year Life Cycle Cost} = (1.48 * \text{Crew size}) + 3.71 \quad (2)$$

$$r^2 = 0.9989; n = 4; p = 0.0005$$

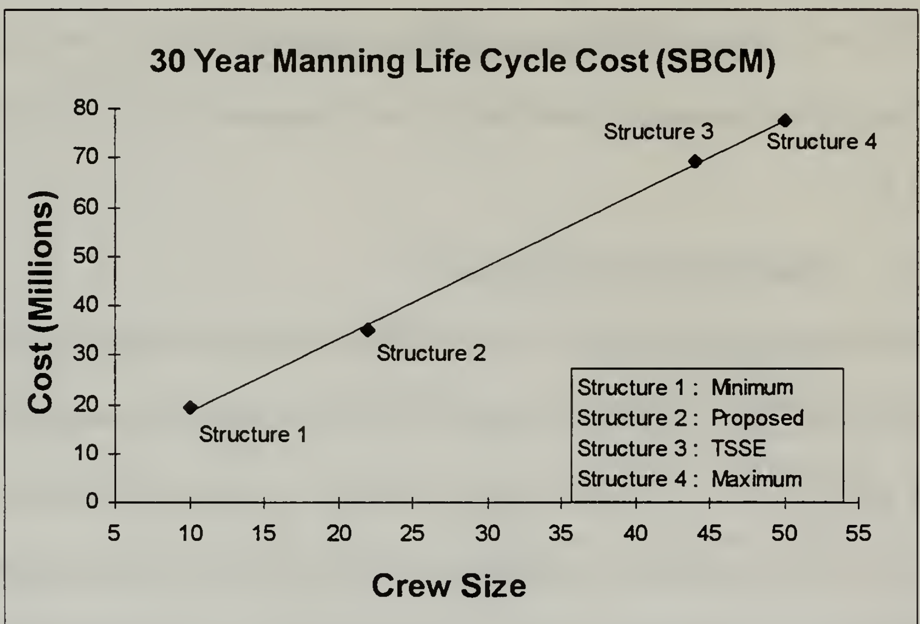

Figure 2. Initial Simplified Billet Cost Model Results

E. MODEL COMPARISON

As can be seen in Figure 3, both models produced similar slopes for the 30 year manning LCC curve with constant dollars. The difference between the slopes is 0.32. The

SBCM underestimates manning LCCs because accession costs, healthcare costs, specialty pay, etc. are not included in the model. To include an estimator for these costs and calibrate the SBCM, the absolute difference between the models was calculated for each manning structure. The proportionate difference was then calculated, to reduce the compounding difference between the models as manning increased, using the NBCF Model. The results are provided in Table 8. The mean proportionate difference is $\overline{X} =$ 0.1861, with a standard deviation of $s = 0.0097$. Since the distribution of the estimated factor is unknown, Chebyshev's inequality is used to determine a confidence interval. A correction factor of 0.15 ($\overline{X} - 3s$) is used to maintain 94 percent confidence that the true factor is not less than the estimate. Equation 3 shows the relationship between the NCBF Model Estimate (Calibrated SBCM) and the SBCM.

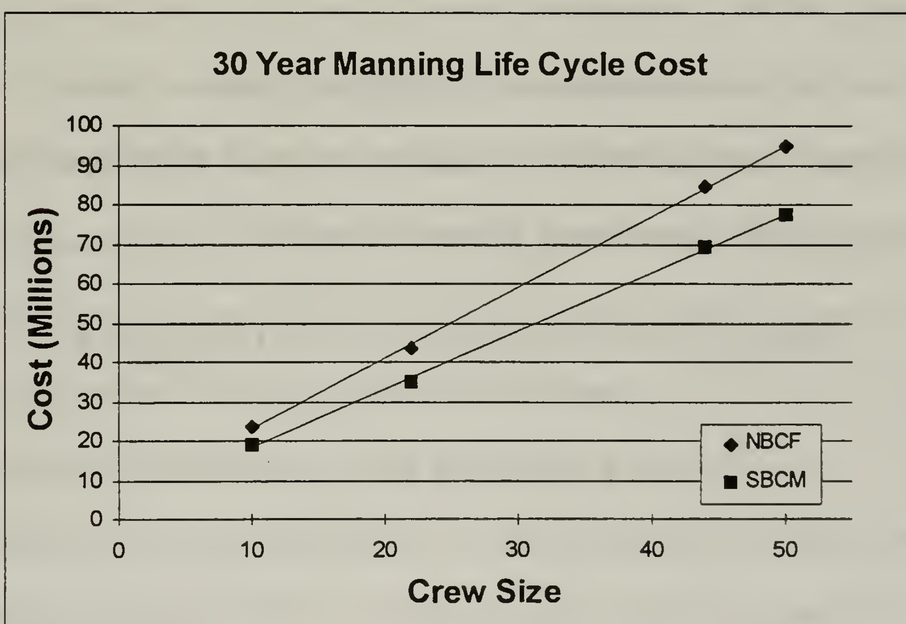

Figure 3. NBCF and SBCM Comparison

Crew Size	Model Results		Difference Between NBCF and SBCM	Proportionate Difference[1]	NBCF Model Estimate	Difference Between NBCF and NBCF Model Estimate
	NBCF	SBCM				
10	23.41	19.20	4.21	0.1797	22.78	0.63
22	43.79	35.01	8.78	0.2005	41.53	2.26
44	84.61	69.26	15.35	0.1815	82.16	2.45
50	94.68	77.37	17.31	0.1828	91.79	2.89

[1] Proportionate Difference = Difference Between NBCF and SBCM / NBCF Results

[2] NBCF Model Estimate = (0.15 * MBCF Model Result) + SBCM Result

Table 8. SBCM Calibration Utilizing the NBCF Model

$$\text{NBCF Model Estimate} = (0.15 * \text{NBCF Model Actual}) + \text{SBCM Results} \quad (3)$$

Since the NBCF Model Estimate is approximately equal (within 6%) to the NBCF Model Actual Result, substituting the NBCF Model Estimate for the NBCF Model Actual in Equation 3 and solving for the NBCF Model Estimate yields:

$$\text{NBCF Model Estimate} = 1.18 * \text{SBCM} = \text{Calibrated SBCM} \quad (4)$$

The results from the NBCF Model , SBCM, and NCBF Model Estimate are compared in Figure 4. The calibrated 30 year LCC curve is :

$$\text{Calibrated 30 Year Life Cycle Cost} = (1.75 * \text{Crew size}) + 3.74 \quad (5)$$

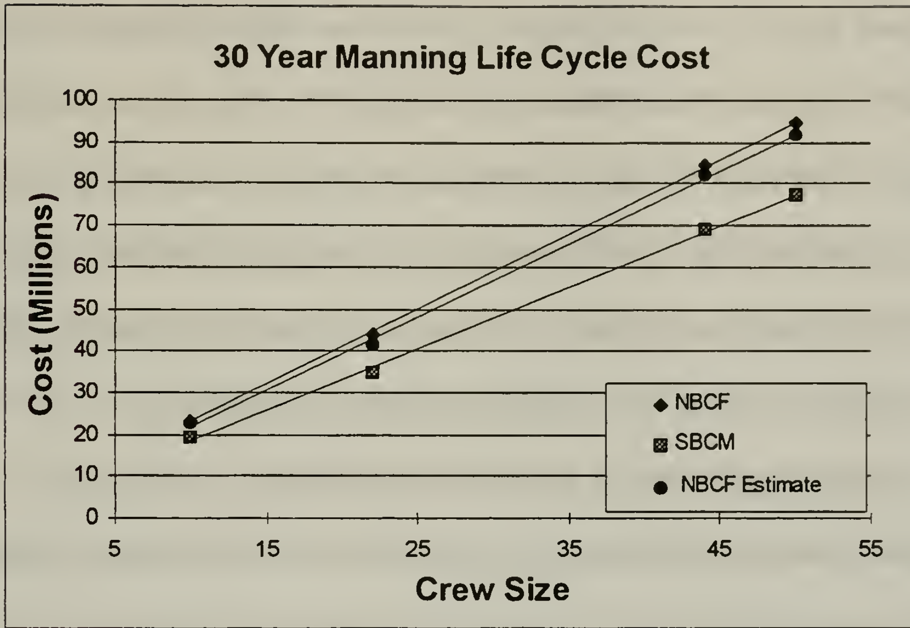

Figure 4. NBCF Model, SBCM, and NBCF Model Estimate Comparison

Since the SBCM underestimates the LCC, the maximum amount to spend in automation will also be underestimated. This provides a built-in buffer ensuring the maximum amount to spend on automation is not overestimated. The SBCM has the advantage of being a spreadsheet model, which makes it easier to use. Furthermore, it can be updated to include San Diego VHA rates and 1997 cost data which makes it more accurate for the purposes of this thesis. Therefore, the calibrated SBCM was used to produce the 30 year manning LCC curve using current year dollars and pay charts, which is the basis for Arsenal Ship manning analysis in this thesis.

F. INDIVIDUAL ARSENAL SHIP MANNING ANALYSIS

Once the 30 year manning LCC curve is determined, it can be used to calculate the cost of adding an additional billet to the billet structure of a single Arsenal Ship. The slope of the curve is the cost per billet over the 30 year service life of the Arsenal Ship.

The maximum amount available to invest in automation, while remaining cost-effective, is determined by calculating the difference between the LCC of the current manning level and the LCC of the proposed manning level and multiplying by the cost per billet obtained from the slope of the LCC curve. For example, using the calibrated SBCM result (Equation 5), the estimated maximum investment in automation to offset a reduction in manning from 44 (Structure 3) to 22 (Structure 2), is $38.5 million.

G. ARSENAL SHIP TOTAL PROGRAM MANNING ANALYSIS

Since maintenance and training are supported ashore, the Squadron Staff and Overhaul Detachment in homeport as well as the Maintenance Detachments at the FOBs must also be considered. As the number of deploying personnel is reduced, the number of support personnel ashore must increase if maintenance requirements remain the same. In some cases, maintenance requirements may increase as the maintenance responsibility is shifted ashore. In order to calculate manning costs, a proposed manning structure had to be designed. Appendix B details a proposed Squadron Staff and Overhaul Detachment as well as a proposed Maintenance Detachment for the purpose of this thesis.

Now that a model to determine the cost of additional manning per ship has been developed, the total program cost of adding an additional billet to the Arsenal Ship can be calculated. Since this thesis assumes a crew deploys from a FOB every four weeks and it takes 36 weeks to cycle a crew, as discussed in Chapter II, nine crews are required to man five Arsenal Ships. Therefore, each additional billet costs the total Arsenal Ship program nine times the cost of adding a single billet to one ship.

H. AUTOMATION COST

In addition to calculating the LCC curve for manning, the cost curve for manning vs. automation is useful. Minimizing the combined LCC for manning and the cost curve for automation identifies an initial crew target size and the optimal investment in automation. The automation cost curve should be calculated by each contractor and supplied as part of their bid proposal since it is dependent on how their design implements innovations in automation. The Navy currently has no data base for estimating a manning vs. automation cost curve. The Naval Center for Cost Analysis maintains the Navy's historical data using the Navy Visibility and Management of Operations and Support Costs (VAMOSC) [Ref. 13]. VAMOSC does not contain the data required to calculate an automation cost curve since there are no systems specifically designed for the purpose of reduced manning.

The civilian sector does maintain automation cost data. McDermott Shipbuilding Incorporated provided automation cost data for a 524 ft. container ship. Their designs include unmanned engine rooms, with crew sizes ranging from 13 to 19 personnel. The manning structure for a crew of 19 is provided in Table 9. The cost of automation, to reduce a crew by approximately 20 personnel, is $275,000 to $325,000 in material and 5,000 man hours of labor [Ref. 14]. Since a container ship does not man weapon systems, the cost of automation is in updating engineering and bridge control stations.

The TSSE design team calculated a unit cost of $487 million for the Arsenal ship. This includes the acquisition cost of the T-AO, combat systems upgrades, and automation costs using Smart Ship Implementation costs [Ref. 9]. To estimate the cost of automating

Job Description	Quantity
Captain	1
Chief Engineer	1
1st Officer	1
1st Engineer	1
2nd Officer	2
2nd Engineer	2
Radio Officer	1
Boswainmate	1
Cook	1
Fitter (cook help)	1
Seaman	1
Motormen	3

Table 9. Manning Design by McDermott Shipbuilding Inc.

the Arsenal Ship, the acquisition cost ($167 million) and the Vertical Launch System cost ($215 million) are subtracted from the unit cost since neither cost contributes to automation. The remainder, approximately $105 million, is the estimated cost of automating the Arsenal Ship under the TSSE design. Not all of the $105 million is directly related to automation cost. Therefore, this is an overestimate of automation cost.

IV. RESULTS

A. INDIVIDUAL ARSENAL SHIP MANNING RESULTS

1. Constant Dollars

A 30 year manning LCC for a single Arsenal Ship was calculated using the calibrated SBCM along with 1997 pay charts and 1997 VHA rates for San Diego. Table 10 provides the results from the model.

Manning Structure	Crew Size	Calibrated SBCM Results (Millions)
Minimum	10	23.75
Proposed	22	43.21
TSSE	44	85.43
Maximum	50	96.20

Table 10. Calabrated SBCM Results

Figure 5 provides the linear regression utilizing the results from the model. The regression equation is:

$$30 \text{ Year Life Cycle Cost} = (1.83 * \text{Crew size}) + 4.40 \quad (6)$$

$$r^2 = 0.9990;\ n = 4;\ p = 0.0005$$

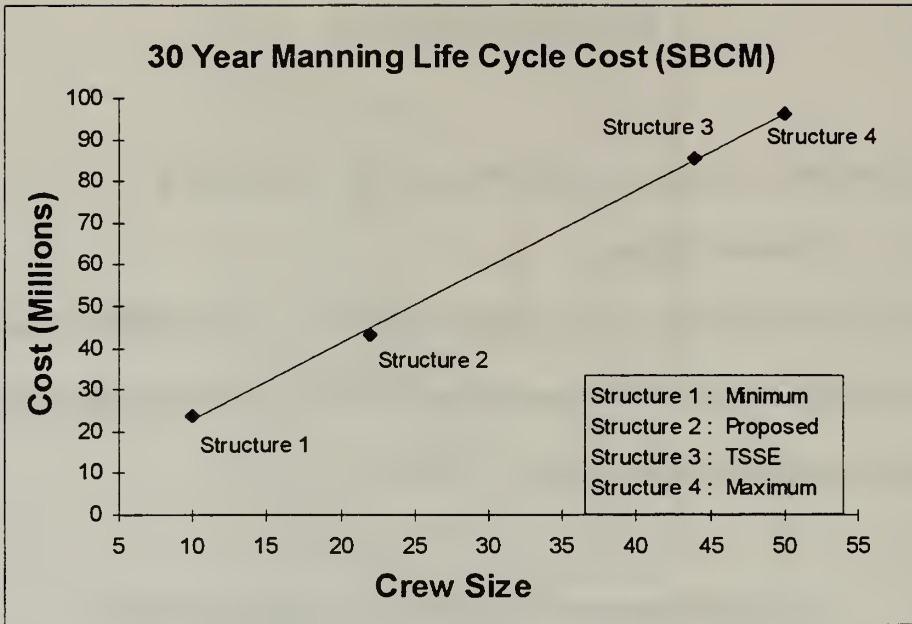

Figure 5. Simplified Billet Cost Model Results, Constant FY 97 Dollars

The 30 year manning LCC curve slope of 1.83 remains consistent with the cost curves obtained from the NBCF and the SBCM in Chapter III. Using Equation 6 above, the maximum investment in automation (constant FY 97 dollars) to offset a reduction in manning from 44 (Structure 3) to 22 (Structure 2) is $40.3 million. When considering the construction of a single Arsenal Ship, using the TSSE design, it would be cost-effective to spend an additional $40.3 million in automation to reduce the crew size by 22 crew members. The total TSSE design cost would increase from $487 million to $527 million, which is below the maximum allowed acquisition cost of $550 million [Ref. 9].

2. Inflation

Since automation cost is considered an initial investment cost in this thesis, inflation does not affect automation cost. However, inflation does affect manning cost throughout the 30 year service life. Therefore, a 30 year manning LCC for a single

Arsenal Ship was calculated using the calibrated SBCM with an annual three percent inflation rate, 1997 pay charts and 1997 VHA rates for San Diego. Table 11 provides the results from the model.

Manning Structure	Crew Size	Calabrated SBCM Results (Millions)
Minimum	10	37.66
Proposed	22	68.52
TSSE	44	135.49
Maximum	50	152.56

Table 11. Calabrated SBCM Results with 3% Annual Inflation

Figure 6 provides the linear regression utilizing the results from the model. The regression equation is:

$$30 \text{ Year Life Cycle Cost} = (2.91 * \text{Crew size}) + 6.98 \tag{7}$$

$$r^2 = 0.9990;\ n = 4;\ p = 0.0005$$

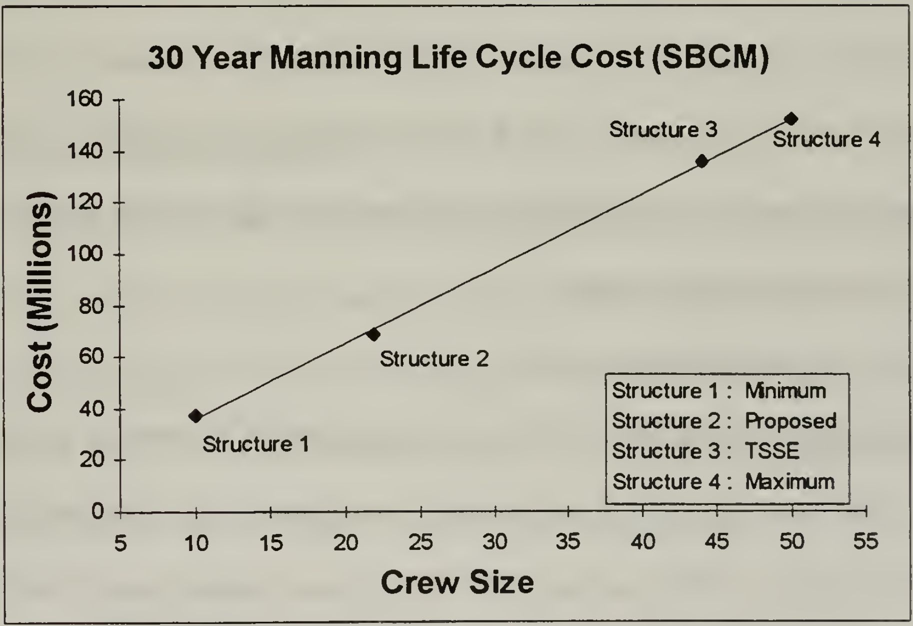

Figure 6. Simplified Billet Cost Model Results, 3% Annual Inflation

Using the TSSE design and Equation 7, it would be cost-effective to spend $64 million on automation to reduce the crew size from 44 to 22 crew members. The total TSSE design cost would increase from $487 million to $551 million, which is one million dollars more than the maximum allowed acquisition cost.

B. ARSENAL SHIP TOTAL PROGRAM MANNING RESULTS

1. Additional Billet Costs

Now that the cost of additional manning per ship has been determined, the impact of adding an Arsenal Ship billet to the entire Arsenal Ship program can also be calculated. As discussed in Chapter III.G, each additional Arsenal Ship billet costs nine times the cost of a single billet. Since inflation affects manning cost, Equation 7 is utilized. The slope from Equation 7 is multiplied by nine to calculate the cost when adding an Arsenal Ship billet to the Arsenal Ship program. Therefore, the cost of adding one Arsenal Ship billet is $26 million ($2.85 million * 9). The maximum cost-effective investment in automation to reduce the crew size by 22 crew members is $572 million. Consequently, $114.4 million would be available for automation in each of the five ships. This method to estimate the investment in automation is valid as long as the number of ships and the number of crews required to man the ships are known.

2. Annual Manning Costs

Using the calibrated SBCM, Equation 6 (constant FY 97 dollars), and the manning structures detailed in Appendix B, the estimated manning cost of a Squadron Staff and Overhaul crew is $7.7 million per year while the estimated manning cost of each FOB maintenance detachment is $5.6 million per year. Therefore, the total annual program manning cost is approximately $32 million for five Arsenal Ships with manning Structure 2 and two FOBs. Figure 7 displays a proportional representation of the annual total program manning cost.

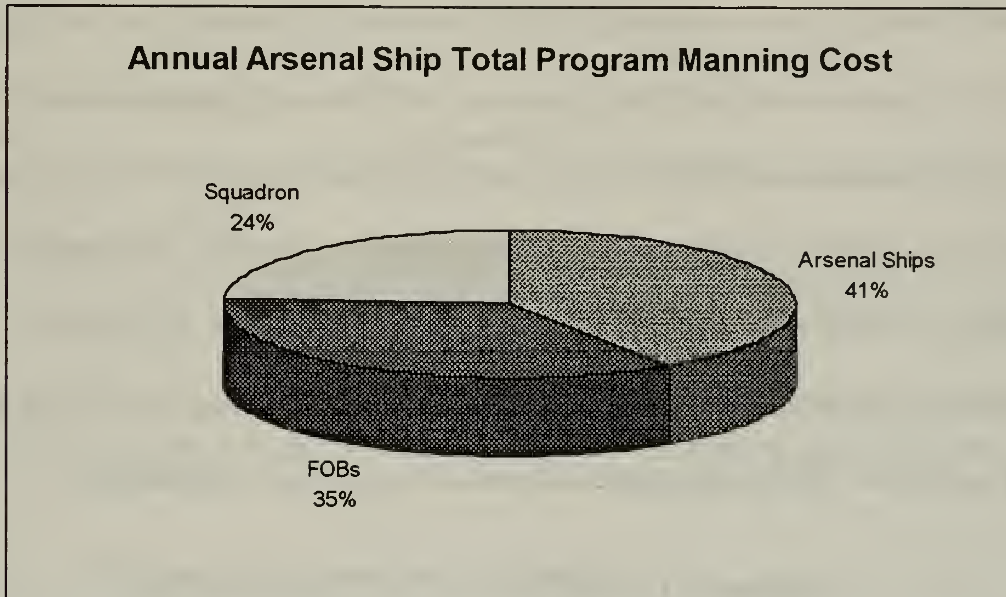

Figure 7. Proportional Annual Total Program Manning Cost Using Structure 2

C. AUTOMATION RESULTS

Before the automation cost curves are discussed, a modification to the 30 year LCC must be identified. Since the automation cost curve will reflect the cost of automation for one ship, the 30 year manning LCC must be scaled to reflect the mean cost of manning per ship. This thesis identified nine crews for five ships. Therefore, the LCC curve must be factored by 9/5. The modified 30 year LCC curve is:

$$\text{Mean 30 Year Life Cycle Cost} = (5.24 * \text{Crew size}) + 12.56 \qquad (8)$$

1. Linear Automation Cost Curve

After identifying a 30 year LCC curve and an automation cost curve, the combined cost curves can be used to identify an initial target crew size and optimal investment in automation. Since generalized automation cost data is unavailable and the cost curve depends on the particular technology utilized, the author developed an automation cost curve for illustration purposes only. Assuming the TSSE design can be manned by a crew of 100 with minimal automation cost ($1 million) and the estimated automation cost for a crew of 44 calculated in Chapter III.G ($105 million) is reasonable, the automation cost to reduce manning by 54 crew members (100 - 44) is $104 million. This yields an automation cost slope of 1.9. Using this slope and the TSSE design cost of $105 million for a crew of 44 , the following linear automation cost curve was formulated:

$$\text{Automation Cost (millions)} = (-1.9 * \text{Crew size}) + 189 \tag{9}$$

Treating the mean LCC curve as a supply curve and the linear automation curve as a demand curve, the optimal investment in automation can be determined by adding the two curves. The minimum point on the combined curve (called the average total cost curve in economics) is the optimal investment in automation. The mean LCC curve (Equation 8), linear automation cost curve (Equation 9) and the combined cost curve are depicted in Figure 8. In this example, the target crew size is 0, or the minimum point of the combined cost curve. This corresponds to a 30 year manning LCC of $13 million. The optimal investment in automation is $189 million. The total combined investment in manning and automation is $202 million per ship. The results indicate that a linear automation cost curve is inaccurate at the tails.

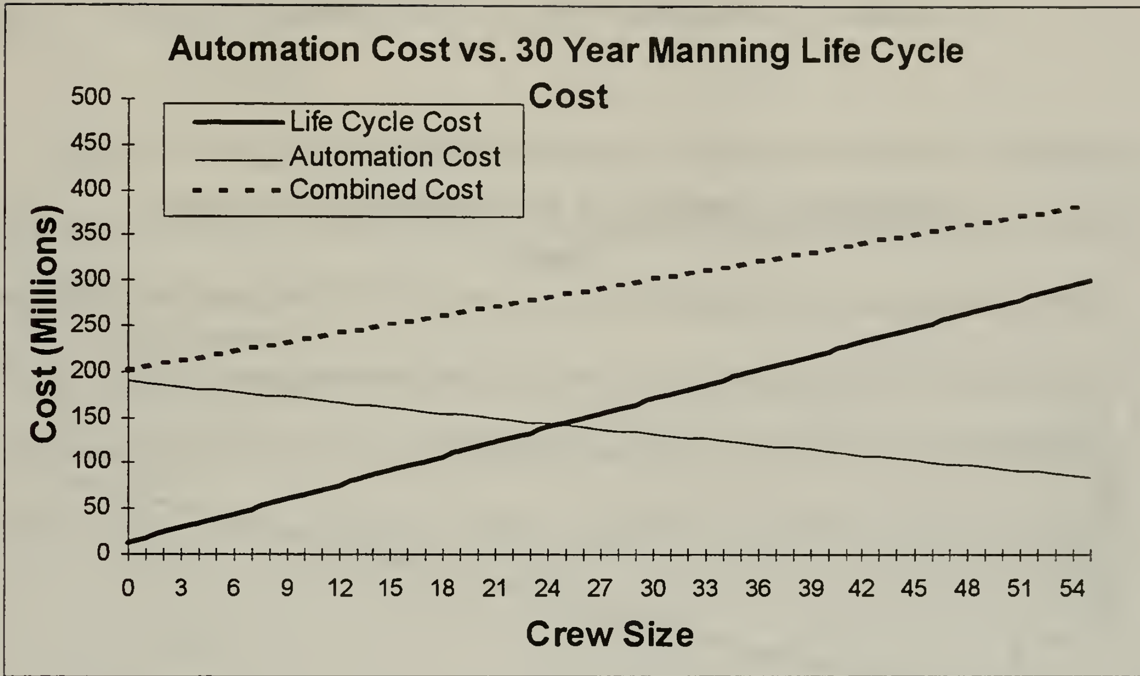

Figure 8. Linear Automation cost vs. Mean 30 Year Manning Life Cycle Cost

2. Exponential Automation Cost Curve

As the crew size approaches zero, the expected cost of technology increases dramatically. Therefore, the automation cost per man increases rapidly as well. On the other hand, as crew size approaches a level in which a four section watch rotation can be implemented, the cost of automation approaches zero because the manning can be reduced by reducing the watch rotation. Therefore, an exponential function was also formulated because it produces more realistic results at the tails. A substantially large value, the maximum allowed procurement cost for the Arsenal Ship ($550 million), was selected as the cost for total automation (y-intercept). Lambda was determined by forcing the function through the estimated automation cost of $105 million for 44 crew members and solving for lambda. The following exponential automation cost curve was formulated:

$$\text{Automation Cost (millions)} = 550\, e^{-(\lambda * \text{Crew size})} \quad \text{where } \lambda = 0.04 \qquad (10)$$

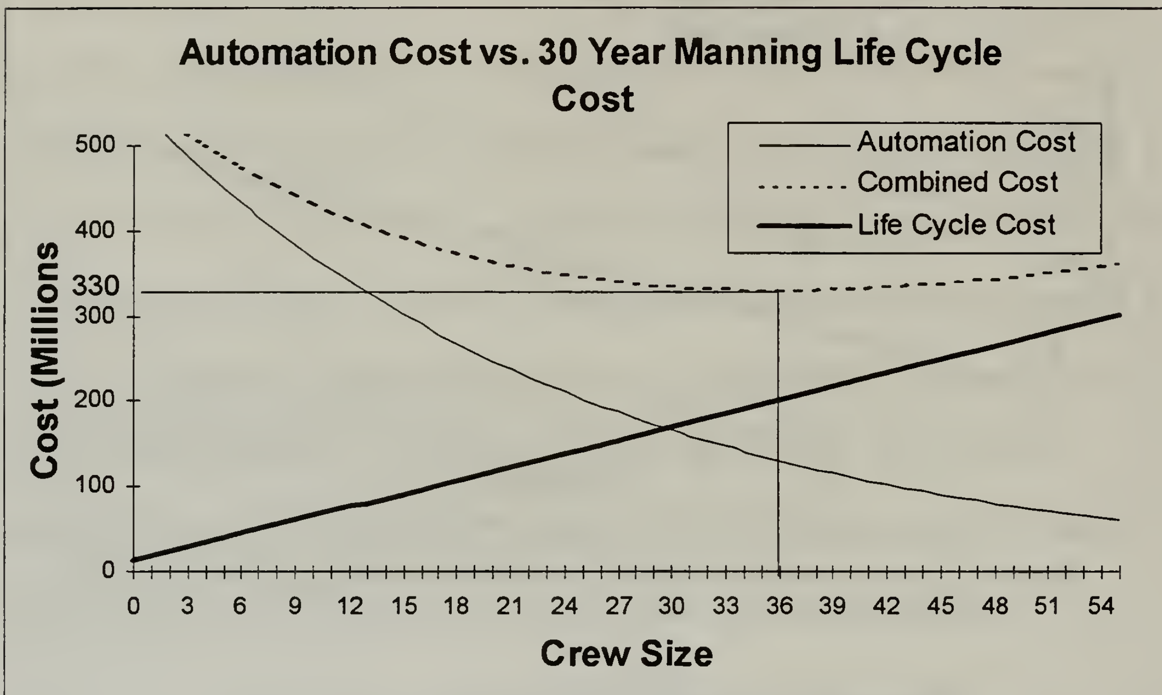

Figure 9. Exponential Automation Cost vs. Mean 30 Year Manning Life Cycle Cost

The mean 30 year manning LCC curve (Equation 8), exponential automation cost curve (Equation 10) and combined cost curve are depicted in Figure 9. The target crew size from the exponential automation cost curve is 36 for a 30 year manning LCC of $200 million. The optimal investment in automation is $130 million and the total investment in manning is $330 million per ship. However, the combined cost curve is so flat around the minimum that a manning level anywhere between 24 and 49 appears to be justified. This is only true, of course, if the exponential automation cost curve is approximately correct.

D. SENSITIVITY ANALYSIS

1. Inflation

Inflation rates tend to fluctuate, therefore, a sensitivity analysis was conducted on inflation. As discussed in Chapter IV.A.2, an increase in inflation will increase the initial investment in automation. The 30 year manning LCC curve from Equation 8, with 2%, 3% and 4% inflation rates is displayed in Figure 10. An increase in annual inflation from the baseline assumption of 3% to 4% will increase the manning LCC for the TSSE design by $47 million. This would imply that $47 million more should be invested in automation.

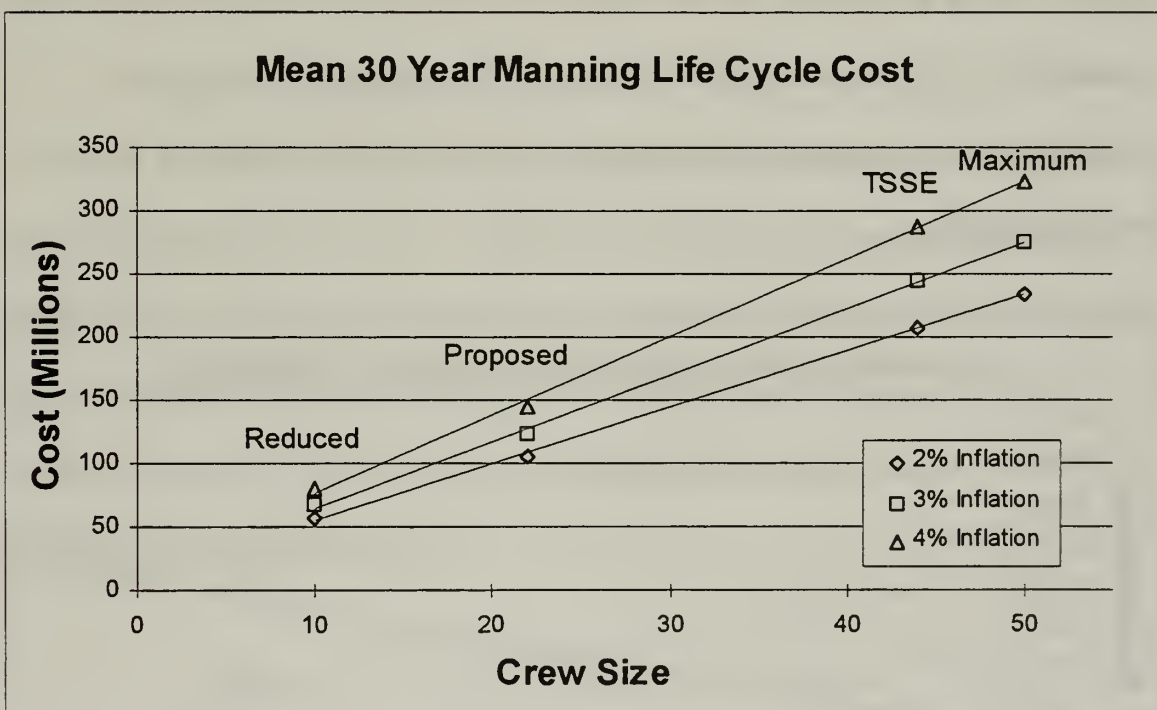

Figure 10. Inflation Sensitivity Analysis

2. Cost Curves

a. Linear Cost Curve

Sensitivity analysis was conducted on the linear automation cost curve by adjusting the slope and resolving for the intercept. The linear cost curve indicates that a combination of maximum automation and zero manning is optimal, until the magnitude of the slope is equal to the magnitude of the mean 30 year manning LCC curve as displayed in Figure 8. When these magnitudes are equal, the slope of the combined cost curve is zero as in Figure 11. In this case, the minimum combined cost is $233 million. However an unlimited number of cost-effective automation/manning combinations exists. If the magnitude of the automation cost curve slope exceeds the magnitude of the mean 30 year manning LCC curve, the linear cost curve indicates no automation, as in Figure 12. Therefore, a linear automation cost curve provides an all or nothing result and should be avoided if possible.

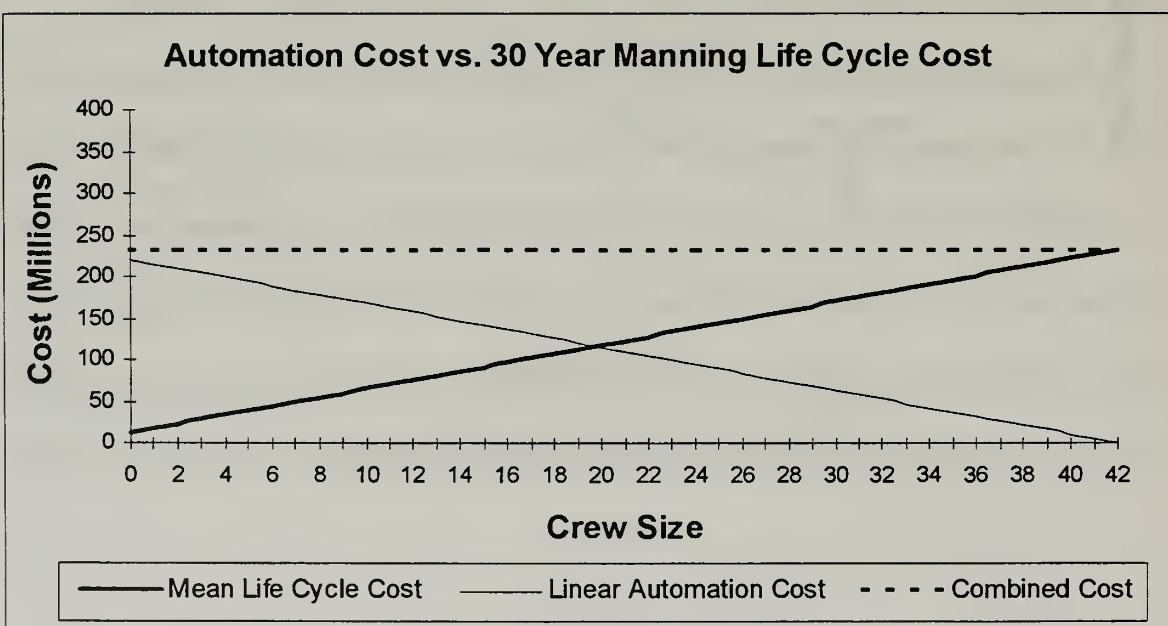

Figure 11. Sensitivity Analysis of Linear Automation Cost Curve (slope = -5.17)

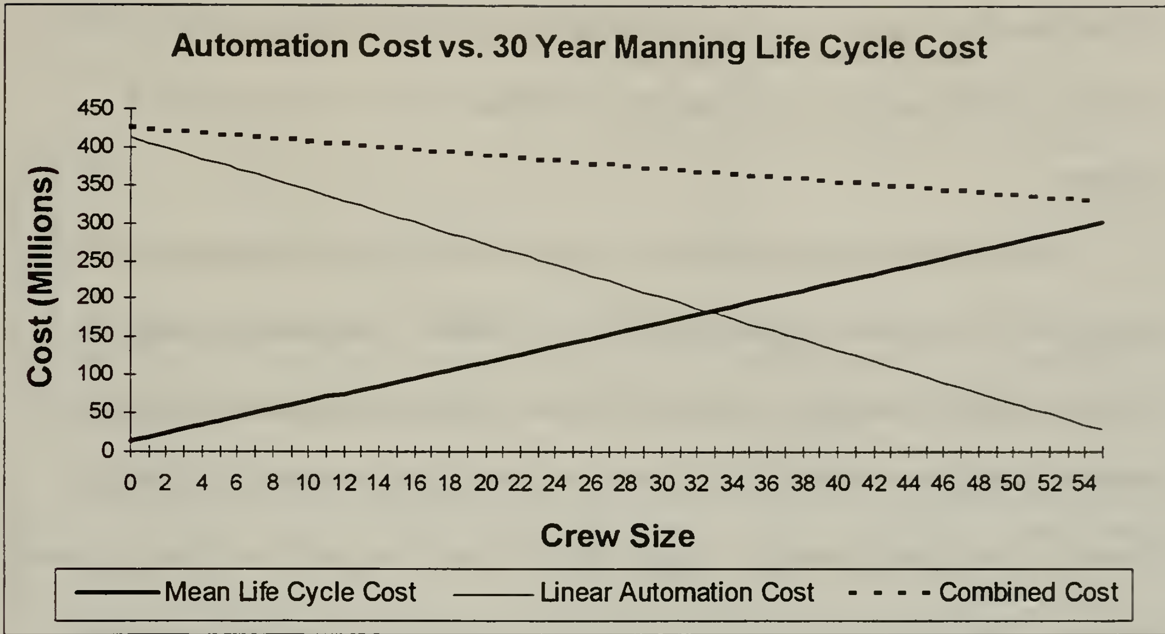

Figure 12. Sensitivity Analysis of Linear Automation Cost Curve (slope = -7)

b. Exponential Cost Curve

Sensitivity analysis was also conducted on the exponential automation cost curve by adjusting lambda $\pm$ 0.01. Since the LCC curve has an increasing slope and the exponential cost curve has a decreasing slope, the minimum of the combined cost curve is where the slopes have the same magnitude with different signs. Equation 11 is the combined cost curve using the LCC curve (Equation 8) and the automation cost curve (Equation 10) with lambda = 0.03.

$$\text{Combined Cost} = (5.24 * \text{Crew size}) + 12.56 + 550\, e^{-(\lambda * \text{Crew size})} \qquad (11)$$

$$\lambda = 0.03$$

Taking the first derivative with respect to crew size yields:

$$5.24 - 16.5\, e^{-(0.03 * \text{Crew size})} \qquad (12)$$

Setting Equation 12 equal to zero and solving for crew size produces a minimum crew size of 38. Following the same procedure for lambda = 0.05, a crew size of 34 is obtained.

The minimum cost and crew size can also be determined by graphing the magnitude of the slopes as displayed in Figure 13. Figure 14 displays the change in combined cost with respect to a change in lambda.. The crew size ranges from 34 to 39, while the optimal investments in automation range from $100 million to $171 million. Therefore, the optimal investment in automation is sensitive to the slope of the exponential cost curve; however, the target crew size is not very sensitive to changes in the slope.

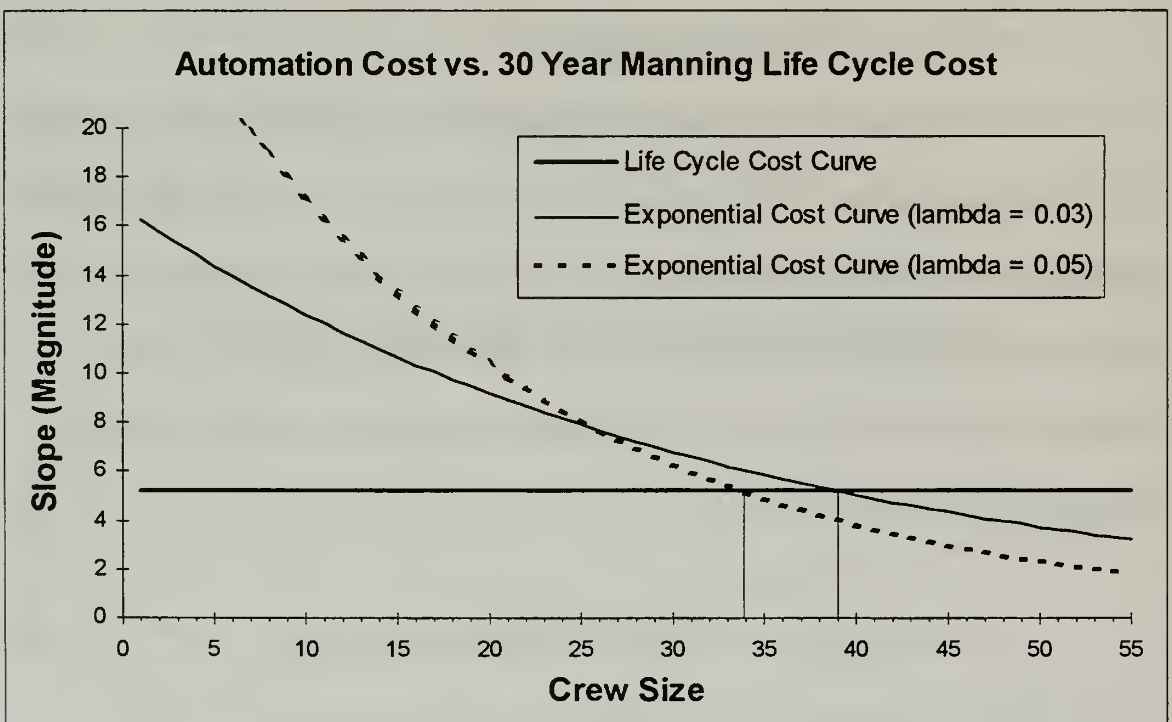

Figure 13. Sensitivity Analysis of Exponential Automation Cost Curve

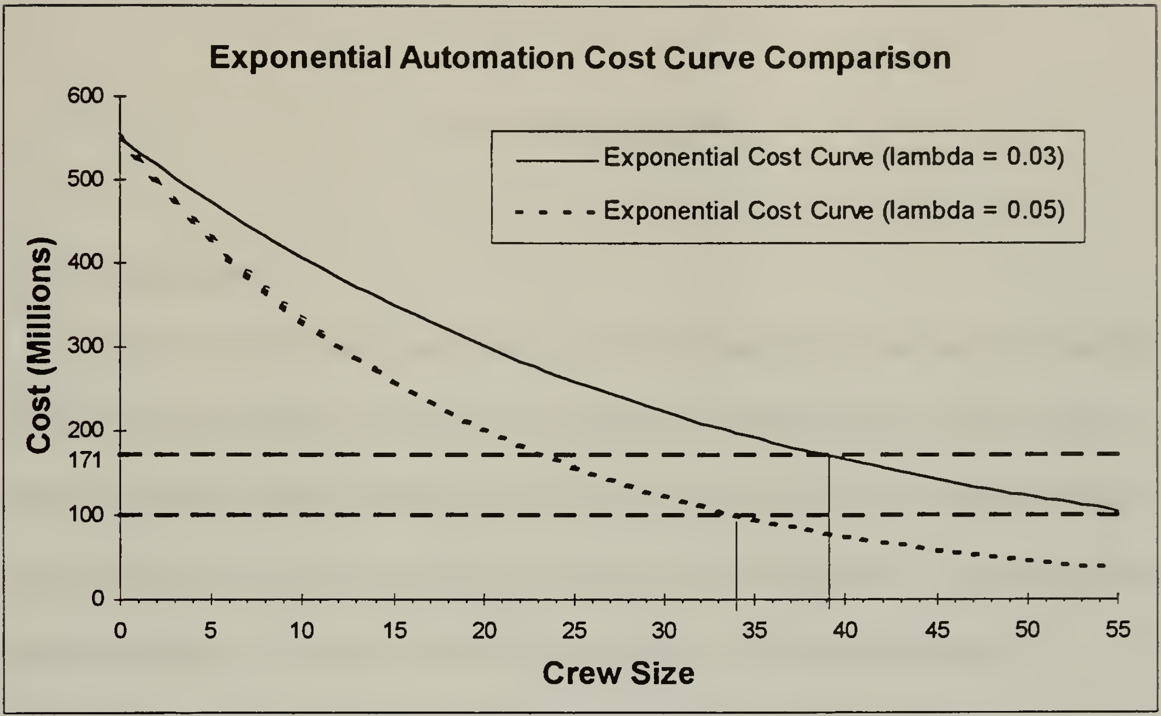

Figure 14. Exponential Automation Cost Curve Comparison

V. CONCLUSION

A. SUMMARY

As the intensifying national concern over the federal deficit continues to impact the budget for national defense, innovations in automation must be utilized to reduce LCCs. However, safety must not be sacrificed to achieve this goal. A tradeoff analysis between automation and manning should be conducted early in the design phase. Since the process of designing ships is changing, commencing with the Arsenal Ship, an excellent opportunity exists to incorporate manning analysis into the design phase.

This thesis identified the manning requirements and the operational requirements affecting manning as outlined in the ASRD. The TSSE design concept was adopted as a baseline for manning. To determine the required number of ships and crews, separate deployment cycles were developed for the Arsenal Ship and the Arsenal Ship crew. The manning structures for special evolutions were developed to assist in identifying minimum manning levels. Damage control manning was determined to be the overall limiting factor. The SBCM is a simplified, updated costing model designed to calculate a 30 year manning LCCs for different manning structures. The TSSE design manning structure was used as the starting point to develop three additional manning structures. Using these four structures and data from the mid 1990s, the results from the SBCM, were compared to the NBCF Model. After the SBCM was calibrated, both models produced similar results. Therefore, the SBCM was used to compute 30 year manning LCCs for the four structures using 1997 pay tables. The LCCs were then used to determine 30 year LCC curves, which were used to conduct cost tradeoff analysis between manning and shipboard automation. Finally, the 30 year LCC curve, in conjunction with an automation cost curve, can also be utilized to calculate an initial crew target size and an optimal investment in automation. This thesis is intended as an analysis tool; it does not provide the answer to minimum manning requirements for the Arsenal Ship because the cost of automation per billet saved does not exist in the Navy cost data.

B. CONCLUSIONS

The Arsenal Ship resembles a logistics platform which is intended to go in harm's way. Therefore, it should be designed for minimum manning. Manning vs. automation tradeoff analysis should be implemented in the design phase of all ships. However, before outfitting ships with the latest technological advances in automation, manning and projected operational tempo (OPTEMPO) should be analyzed. Manning structures should be compared after identifying the limiting factor or factors, which is damage control in this thesis.

Deployment cycles for crews and ships should be designed as a "steady state" process. Slack should be included to allow room for adjustment without causing a ripple effect as minor delays arise. The deployment schedule developed for this thesis requires five, not six, Arsenal Ships. Four are forward deployed at two FOBs, while one is in overhaul at homeport. This allows 100 percent coverage of two theaters of operation. The training and deployment cycle requires nine deployment crews. Four of the nine are embarked and five of the nine are in training or in transit to or from the FOBs.

The data required to support an automation cost curve is not readily available in the Navy. However, as systems are designed or modified for the purpose of reduced manning, the data should be collected and analyzed. With increasing manning cost, retrofitting ships with the technology which does not support reduced manning is ill-advised. Every billet in the Arsenal Ship should be completely justified.

C. RECOMMENDATIONS

I recommend challenging the design teams to build an Arsenal Ship that balances marginal automation cost with marginal manning cost. Efficiencies in manning must be realized as budgets are reduced. The design concept should force reductions in manning towards the lower bound, whether the lower bound is cost related or technology related.

The NBCF Model should be updated to provide more flexibility. The current model's options are limited and updating the data is a very difficult if not an impossible task. A model that cannot be updated by the user becomes inaccurate and thus obsolete quickly.

Program managers should be encouraged to conduct automation vs. manning tradeoff analysis prior to solicitation of contracts. Likewise, contractors should provide their automation vs. manning tradeoff analysis early in the contract process to ensure such analysis is a part of the design phase.

D. FURTHER STUDY

Since this thesis does not have the information to develop a valid automation cost curve, the most obvious area for further research is to compile actual or reasonable data and compute an automation cost curve as a function of watchstanding and other crew functions. Likewise, this thesis does not identify the cost of maintaining and operating an Arsenal Ship training simulator, which is an important part of the training process developed in Chapter II.

The NBCF Model could also be updated and revised to include more options. For instance, cost comparisons for different geographical regions could be conducted if the model allowed separate VHA rates to be identified rather than using a weighted average.

APPENDIX A. DEPLOYMENT CYCLES

This appendix contains the proposed Arsenal Ship deployment schedule designed by the author.

Proposed Arsenal Ship Deployment Cycle

<table>
<tr><th></th><th></th><th>M1</th><th>M2</th><th>M3</th><th>M4</th><th>M5</th><th>M6</th><th>M7</th><th>M8</th><th>M9</th><th>M10</th><th>M11</th><th>M12</th><th>M13</th><th>M14</th></tr>
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<tr><td>Guam</td><td>Ship A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Crew</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Ship B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Crew</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Ship C</td><td></td><td>Transit</td><td colspan="3">Deployed</td><td>IMAV</td><td colspan="3">Deployed</td><td>IMAV</td><td colspan="3">Deployed</td><td>IMAV</td></tr>
<tr><td></td><td>Crew</td><td></td><td colspan="4">2</td><td colspan="4">6</td><td colspan="4">1</td><td></td></tr>
<tr><td></td><td>Ship D</td><td></td><td></td><td></td><td>Transit</td><td colspan="3">Deployed</td><td>IMAV</td><td colspan="3">Deployed</td><td>IMAV</td><td colspan="2">Deploye</td></tr>
<tr><td></td><td>Crew</td><td></td><td></td><td></td><td colspan="4">4</td><td colspan="4">8</td><td colspan="3">3</td></tr>
<tr><td></td><td>Ship E</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Crew</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Proposed Arsenal Ship Deployment Cycle

			M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27
FOB															
Diego Garcia	Ship A		eployed		Transit				Overhaul						
	Crew														
	Ship B		IMAV		Deployed		IMAV		Deployed		IMAV		Deployed		IMAV
	Crew			6				10				14			
	Ship C														
	Crew														
	Ship D														
	Crew														
	Ship E				Transit		Deployed		IMAV		Deployed		IMAV		Deploye
	Crew					8				12				16	
Guam	Ship A													IMAV	
	Crew														
	Ship B														
	Crew														
	Ship C			Deployed		IMAV		Deployed		IMAV		Deployed		Transit	
	Crew		5				9				13				
	Ship D			IMAV		Deployed		IMAV		Deployed		IMAV		Deployed	
	Crew				7				11				15		
	Ship E														
	Crew														

Proposed Arsenal Ship Deployment Cycle

			M28	M29	M30	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40
FOB															
Diego Garcia	Ship A														
	Crew														
	Ship B			Deployed		IMAV		Deployed		Transit					Overhaul
	Crew			18				13							
	Ship C									Transit		Deployed		IMAV	
	Crew											17			
	Ship D														
	Crew														
	Ship E			IMAV		Deployed		IMAV		Deployed		IMAV		Deployed	
	Crew					11				15				19	
Guam	Ship A		eployed		IMAV		Deployed		IMAV		Deployed		IMAV		Deploye
	Crew		7				12				16				20
	Ship B														
	Crew														
	Ship C					Overhaul									
	Crew														
	Ship D		IMAV		Deployed		IMAV		Deployed		IMAV		Deployed		IMAV
	Crew				10				14				18		
	Ship E														
	Crew														

Proposed Arsenal Ship Deployment Cycle

FOB			M41	M42	M43	M44	M45	M46	M47	M48	M49	M50	M51	M52	M53
Diego Garcia	Ship A														
	Crew														
	Ship B														
	Crew														
	Ship C		eployed		IMAV		Deployed		IMAV		Deployed		IMAV		Deploye
	Crew		1			25				21				25	
	Ship D														Transit
	Crew														
	Ship E		IMAV		Deployed		IMAV		Deployed		IMAV		Deployed		Transit
	Crew			23				19				23			
Guam	Ship A			IMAV		Deployed		IMAV		Deployed		IMAV		Deployed	
	Crew				24				20				24		
	Ship B					Transit		Deployed		IMAV		Deployed		IMAV	
	Crew						26				22				
	Ship C														
	Crew														
	Ship D			Deployed		Transit				Overhaul					
	Crew		22												
	Ship E														
	Crew														

Proposed Arsenal Ship Deployment Cycle

FOB		M54	M55	M56	M57	M58	M59	M60	M61	M62
Diego Garcia	Ship A									
	Crew									
	Ship B									
	Crew									
	Ship C		IMAV	Deployed			IMAV	Deployed		
	Crew		29				33			
	Ship D	Deployed			IMAV	Deployed			IMAV	
	Crew	27			31				35	
	Ship E	Overhaul								
	Crew									
Guam	Ship A	IMAV	Deployed			IMAV	Deployed			
	Crew	28				32				
	Ship B	eployed		IMAV	Deployed			IMAV		
	Crew	6		30				34		
	Ship C									
	Crew									
	Ship D									
	Crew									
	Ship E									
	Crew									

Arsenal Ship Availability	
Phase	Time
IMAV	17.8%
Transit	4.4%
Deployed	60.0%
Overhaul	17.8%
	100.0%

Three of five ships deployed at any time.
100% coverage of two contingencies.

APPENDIX B. PROPOSED MANNING

This appendix contains the proposed Arsenal Ship, Maintenance Detachment, and Squadron Staff and Overhaul Detachment manning structures designed by the author.

Proposed Arsenal Ship

Watch, Quarter and Station Bill						
Rate/Rank	Billet	Watch	UNREP	Flight Operations	Genral Quarters	
					Damage	Launch
CDR	CO		Bridge	Bridge	Bridge	CIC
LCDR	XO/NAV	OOD	Bridge	Bridge	Bridge	Bridge
LT	OPS	OOD	SO (UNREP)	SO (FLT DECK)	Bridge	Bridge
LT	CSO	OOD	Bridge	Bridge	CIC	CIC
LT/LDO	ENG	EOOW	CCS	CCS	CCS	CCS
ENC		EOOW	MER 1	MER 1	MER 1	MER 1
EM1	ELO	EOOW	MER 2	MER 2	MER 2	MER 2
EN2		Operator	MER 1	OSL	OSL	MER 1
EN2		Operator	MER 2	Team Leader	Team Leader	MER 2
EM2		Operator	CCS	CCS	Electrician	CCS
BM1		JOOD	Rig Captain	LSE	Bridge	Bridge
SM1		JOOD	Signalman	Nozzleman	Nozzleman	Bridge
QM1		JOOD	Bridge / Helm	Bridge / Helm	Bridge / Helm	Bridge / Helm
OS1		COMMS	COMMS	COMMS	COMMS	COMMS
OS2		COMMS	Linehandler	Hoseman	Hoseman	CIC
OS2		COMMS	Linehandler	Hoseman	Hoseman	CIC
ETC	EMO	Sensor Control	Sensor Control	Sensor Control	Sensor Control	Sensor Control
ET1		Sensor Control	Linehandler		Nozzleman	Sensor Control
ET2		Sensor Control	Linehandler	Hotsuitman	Hoseman	Sensor Control
ET2		Sensor Control	Linehandler	Hotsuitman	Hoseman	Sensor Control
MS1	Cook	Galley	Linehandler	Chock and Chain	Plugman	Galley
MS2	Baker	Galley	Linehandler	Chock and Chain	Plugman	Galley

(Definitions included on the following page.)

Acronym	Definition
CCS	Central Control Station (Engineering)
CO	Commanding Officer
COMMS	Communications (Combat Information Center)
CSO	Combat Systems Officer
ELO	Electrical Officer
EMO	Electronics Maintenance Officer
EOOW	Engineering Officer of the Watch
JOOD	Junior Officer of the Deck
LSE	Landing Signalman Enlisted
MER	Main Engine Room
OOD	Officer of the Deck
OPS	Operations Officer
OSL	On Scene Leader
SO	Safety Officer
UNREP	Underway Replenishment
XO/NAV	Executive Officer/ Navigator

Maintenance Detachment (FOB)

Enlisted	
Rate/Rank	Quantity
BMC	1
BM1	2
BM2	4
BM3	6
BMSN	6
DCC	1
DC1	1
DC2	4
DC3	3
DCSN	3
EMC	1
EM1	1
EM2	2
EM3	4
ENC	1
EN1	2
EN2	4
EN3	6
ENSN	2
ETC	1
ET1	2

Enlisted	
Rate/Rank	Quantity
ET2	4
ET3	6
EW1	1
EW2	2
GMGC	1
GMG1	2
GMG2	4
GMG3	4
GMMC	1
GMM1	2
GMM2	4
GMM3	4
PNC	1
PN2	2
PN3	1
SKC	1
SK1	2
SK2	3
SK3	5
YN1	1
YN2	1

Officers		
Rank	Billet	Quantity
CDR	CO	1
LCDR	XO	1
LCDR	SUPPO	1
LT	1st LT	1
LT	EMO	1
LT	ENG	1

Enlisted	109
Officers	6
Total	115

Squadron Staff and Overhaul Detachment (Homeport)

Enlisted	
Rate/Rank	**Quantity**
BMCM	1
BMCS	1
BMC	1
BM1	3
BM2	4
BM3	8
BMSN	8
DCCS	1
DCC	1
DC1	2
DC2	4
DC3	3
DCSN	3
DKC	1
DK1	1
DK2	1
DK3	1
EMC	1
EM1	1
EM2	2
EM3	4
ENCS	1
ENC	1
EN1	2
EN2	4
EN3	6
ENSN	2
ETCS	1
ETC	1
ET1	2
ET2	4

Enlisted	
Rate/Rank	**Quantity**
ET3	6
EW1	1
EW2	2
GMGC	1
GMG1	2
GMG2	4
GMG3	4
GMMC	1
GMM1	2
GMM2	4
GMM3	4
HTC	1
HT1	1
HT2	2
HT3	1
MAC	1
MA1	1
MM1	1
MM2	1
MM3	1
PNCS	1
PN1	1
PN2	2
PN3	1
SKCS	1
SKC	1
SK1	2
SK2	3
SK3	5
YN1	1
YN2	1

Officers		
Rank	**Billet**	**Quantity**
CAPT	CO	1
CDR	XO	1
LCDR	CSO	1
LCDR	MO	1
LCDR	OPS	1
LCDR	SUPPO	1
LT	1st LT	1
LT	ADMIN	1
LT	AMO	1
LT	DISBO	1
LT	EMO	1

Enlisted	136
Officers	11
Total	147

APPENDIX C. TOTAL SHIP SYSTEM ENGINEERING DESIGN

This appendix contains a reproduction of the Naval Postgraduate School's Total System Engineering design team's Watch, Quarter and Station Bill [Ref. 10].

		Billet				Normal	Combat	Bridge		Helo	Boat	Damage
	Crew	Number	Title	Rank	Quals	Steaming	Steaming	Evolutions	UNREP	Operations	Operations	Control
												Physical
												Security
Admin	25	Adm - 501	Corpman	E-6	HM							
	26	Adm -502	Cook	E-6	MS							
	27	Adm -502	Cook	E-4	MS							
Labor	28	LF - 501	Deck Force	E-6	BM	Normal Work	Normal Work	Normal Work	Safety	LSE	Safety	SAT
Force	29	LF - 502	Deck Force	E-5	BM	Normal Work	Normal Work	Normal Work	Winch	Tiedown	Coxswain	SAT
	30	LF - 503	Deck Force	E-5	BM	Normal Work	Normal Work	Normal Work	Linehandler	Tiedown	Boat	SAT
	31	LF - 504	HME Force	E-6	DC	Normal Work	Normal Work	Normal Work	Fuel Sampler	OSL/AFFF		OSL/AFFF
	32	LF - 505	HME Force	E-6	EN	Normal Work	Normal Work	Normal Work	Linehandler	Team Leader	Engineman	Hoseman
	33	LF - 505	HME Force	E-5	EM	Normal Work	Normal Work	Normal Work	Linehandler	Hoseman	Linehandler	Hoseman
	34	LF - 506	HME Force	E-5	DC	Normal Work	Normal Work	Normal Work	Linehandler	Hoseman	Linehandler	Team Leader
	35	LF - 507	Combat Force	E-6	ET	Normal Work	Normal Work	Normal Work	Signals	Hotsuitman		Hoseman
	36	LF - 508	Combat Force	E-6	ET	Normal Work	Normal Work	Normal Work	Phonetalker	Hotsuitman		Plugman
	37	LF - 509	Combat Force	E-5	ET	Normal Work	Normal Work	Normal Work		Plugman		SAT
	38	LF - 510	Combat Force	E-5	ET	Normal Work	Normal Work	Normal Work				SAT
	39	LF - 510	Combat Force	E-6	GMM	Normal Work	Normal Work	Normal Work				SAT
	40	LF - 510	Combat Force	E-5	GMM	Normal Work	Normal Work	Normal Work				SAT
	41	LF - 510	Combat Force	E-4	GMM	Normal Work	Normal Work	Normal Work	Linehandler	Phonetalker		SAT
	42	LF - 510	Combat Force	E-4	GMM	Normal Work	Normal Work	Normal Work	Linehandler			SAT
	43	LF - 510	Combat Force	E-4	GMM	Normal Work	Normal Work	Normal Work				SAT
	44	LF - 510	Combat Force	E-4	GMM	Normal Work	Normal Work	Normal Work				SAT

Table III-9. Watch, Quarter and Station Bill for Special Evolutions

		Billet				Normal	Combat	Bridge		Helo	Boat	Damage
	Crew	Number	Title	Rank	Quals	Steaming	Steaming	Evolutions	UNREP	Operations	Operations	Control
												Physical
Command	1	Ops - 100	Captain	O-5/6	SWO							Security
	2	Eng - 100	Maintenance Officer	O-4	LDO							
Watch	3	Ops - 201	OOD	O-3	SWO	OOD #1	OOD #1	OOD #1	OOD #1	OOD #1	OOD #1	OOD #1
	4	Ops - 202	OOD	O-3	SWO	OOD #2	OOD #2	OOD #2	OOD #2	OOD #2	OOD #2	OOD #2
	5	Ops - 203	OOD	O-3	SWO	OOD #3	OOD #3	OOD #3	OOD #3	OOD #3	OOD #3	OOD #3
	6	Ops - 204	OOD	O-3	SWO	OOD #4	OOD #4	OOD #4	OOD #4	OOD #4	OOD #4	OOD #4
	7	Ops - 301	JOOD/lookout	E-7/8	QM	JOOD #1	JOOD #1	JOOD #1	JOOD #1	JOOD #1	JOOD #1	JOOD #1
	8	Ops - 302	JOOD/lookout	E-7/8	QM	JOOD #2	JOOD #2	JOOD #2	JOOD #2	JOOD #2	JOOD #2	JOOD #2
	9	Ops - 303	JOOD/lookout	E-7/8	QM	JOOD #3	JOOD #3	JOOD #3	JOOD #3	JOOD #3	JOOD #3	JOOD #3
	10	Ops - 304	JOOD/lookout	E-7/8	QM	JOOD #4	JOOD #4	JOOD #4	JOOD #4	JOOD #4	JOOD #4	JOOD #4
	11	Com - 201	CSO	O-4	SWO	CSO #1	CSO #1	CSO #1	CSO #1	CSO #1	CSO #1	CSO #1
	12	Com - 202	CSO	O-3	SWO	CSO #2	CSO #2	CSO #2	CSO #2	CSO #2	CSO #2	CSO #2
	13	Com - 301	COMMS	O-3	RM	COMMS #1	COMMS #1	COMMS #1	COMMS #1	COMMS #1	COMMS #1	COMMS #1
	14	Com - 302	COMMS	E-6	RM	COMMS #2	COMMS #2	COMMS #2	COMMS #2	COMMS #2	COMMS #2	COMMS #2
	15	Com - 401	SD	E-6	EW	SD #1	SD #1	SD #1	SD #1	SD #1	SD #1	SD #1
	16	Com - 402	SD	E-5	EW	SD #2	SD #2	SD #2	SD #2	SD #2	SD #2	SD #2
	17	Eng - 201	EOOW	E-7	EN	EOOW #1	EOOW #1	EOOW #1	EOOW #1	EOOW #1	EOOW #1	EOOW #1
	18	Eng - 202	EOOW	E-7	EN	EOOW #2	EOOW #2	EOOW #2	EOOW #2	EOOW #2	EOOW #2	EOOW #2
	19	Eng - 203	EOOW	E-7	EM	EOOW #3	EOOW #3	EOOW #3	EOOW #3	EOOW #3	EOOW #3	EOOW #3
	20	Eng - 204	EOOW	E-7	EM	EOOW #4	EOOW #4	EOOW #4	EOOW #4	EOOW #4	EOOW #4	EOOW #4
	21	Eng - 205	EO	E-6	EN	EO #1	EO #1	EO #1	EO #1	EO #1	EO #1	EO #1
	22	Eng - 206	EO	E-6	EN	EO #2	EO #2	EO #2	EO #2	EO #2	EO #2	EO #2
	23	Eng - 207	EO	E-5	EN	EO #3	EO #3	EO #3	EO #3	EO #3	EO #3	EO #3
	24	Eng - 208	EO	E-5	EM	EO #4	EO #4	EO #4	EO #4	EO #4	EO #4	EO #4

Table III-8. Watch, Quarter and Station Bill for Watchstanders

APPENDIX D. SIMPLIFIED BILLET COST MODEL RESULTS

This appendix contains the Excel® spreadsheet format utilized for the SBCM including the data and the results.

Reduced

							36.40%		
Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	0	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	0.00
E4	0	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	0.00
E5	2	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	6824.85
E6	2	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	8059.26
E7	1	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	5186.99
E8	0	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	0.00
E9	0	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	0.00
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	3	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	19506.15
O4	1	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	7500.01
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	0	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	0.00
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	10								55899.7536
									x12
									670797.0432

Annual Inflation Rate	30 Year Manning LCC
2%	27212947.58
3%	31913448.18
4%	37621610.41

Proposed

							36.40%		
Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	0	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	0.00
E4	0	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	0.00
E5	8	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	27299.39
E6	7	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	28207.41
E7	2	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	10373.97
E8	0	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	0.00
E9	0	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	0.00
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	3	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	19506.15
O4	1	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	7500.01
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	0	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	0.00
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	22								101709.43
									x12
									1220513.16

Annual Inflation Rate	30 Year Manning LCC
2%	49513874.55
3%	58066420.96
4%	68452404.60

TSSE

							36.40%		
Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	0	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	0.00
E4	5	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	13338.20
E5	10	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	34124.23
E6	12	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	48355.56
E7	6	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	31121.92
E8	2	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	11342.13
E9	0	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	0.00
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	6	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	39012.30
O4	2	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	15000.01
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	0	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	0.00
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	44								201116.868
									x12
									2413402.416

Annual Inflation Rate	30 Year Manning LCC
2%	97907100.37
3%	114818623.21
4%	135355524.27

Maximum

							36.40%		
Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	0	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	0.00
E4	5	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	13338.20
E5	14	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	47773.92
E6	12	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	48355.56
E7	7	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	36308.91
E8	2	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	11342.13
E9	0	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	0.00
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	7	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	45514.35
O4	2	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	15000.01
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	0	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	0.00
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	50								226455.5984
									x12
									2717467.181

Annual Inflation Rate	30 Year Manning LCC
2%	110242423.83
3%	129284630.79
4%	152408977.67

FOB

Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement (36.40%)	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	11	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	24335.29
E4	39	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	104037.99
E5	34	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	116022.39
E6	16	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	64474.08
E7	9	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	46682.88
E8	0	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	0.00
E9	0	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	0.00
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	3	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	19506.15
O4	2	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	15000.01
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	0	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	0.00
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	115								398881.2972
									x12
									4786575.566

Annual Inflation Rate	30 Year Manning LCC
2%	194182176.70
3%	227723322.38
4%	268454792.68

Homeport

							36.40%		
Paygrade	Quantity	Basic Pay	Sea Pay	BAQ	BAS	VHA	Retirement	Paygrade Cost	Total Cost
E1	0	900.90	0.00	361.50	0.00	218.50	327.93	1808.83	0.00
E2	0	1010.10	0.00	361.50	0.00	218.50	367.68	1957.78	0.00
E3	13	1196.70	0.00	379.80	0.00	200.20	435.60	2212.30	28759.88
E4	44	1394.70	160.00	408.00	0.00	197.27	507.67	2667.64	117376.20
E5	38	1731.30	350.00	469.20	0.00	231.73	630.19	3412.42	129672.08
E6	23	2040.00	450.00	521.70	0.00	275.37	742.56	4029.63	92681.49
E7	11	2794.80	500.00	564.60	0.00	310.28	1017.31	5186.99	57056.86
E8	6	3106.50	520.00	608.10	0.00	305.70	1130.77	5671.07	34026.40
E9	1	3478.50	520.00	659.70	0.00	317.87	1266.17	6242.24	6242.24
O1	0	2170.80	280.00	490.50	154.16	315.55	790.17	4201.18	0.00
O2	0	2751.60	280.00	548.70	154.16	332.69	1001.58	5068.73	0.00
O3	5	3708.60	290.00	642.60	154.16	356.76	1349.93	6502.05	32510.25
O4	4	4287.90	300.00	776.70	154.16	420.45	1560.80	7500.01	30000.02
O5	1	5128.80	340.00	881.10	154.16	451.56	1866.88	8822.50	8822.50
O6	1	6285.60	380.00	914.10	154.16	435.47	2287.96	10457.29	10457.29
O7	0	7154.40		1015.20	154.16	429.00	2604.20	11356.96	0.00
	147								547605.2164
									x12
									6571262.597

Annual Inflation Rate	30 Year Manning LCC
2%	266583501.50
3%	312630549.76
4%	368548853.68

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